RAPID DEVELOPMENT: A CONTENT ANALYSIS COMPARISON OF LITERATURE AND PURPOSIVE SAMPLING OF AFRL RAPID REACTION PROJECTS

THESIS

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ABSTRACT

In the current environment of military operations requesting faster delivery schedules to counter insurgent tactics, the engineering team often searches for how to quickly deliver the “80% solution”, typically in 6-12 months. These are labeled rapid development projects. A content analysis of best practices in commercial product development literature, where time to market is often a driving factor, was accomplished showing varying emphasis of systems engineering technical and technical management processes. Technical Planning, Stakeholders Requirements Development, and Architecture Design were identified as important processes. This analysis confirms preconceived notions of “plan upfront and early” by emphasizing the SE processes of Stakeholder Requirements Definition, Architecture Design and Technical Planning. A purposive sampling of AFRL rapid development program managers and engineers was conducted to identify important SE processes and compared to the literature content analysis. The results of this sampling did not strongly emphasize one process over another however Architecture Design, Implementation scored higher among Technical Processes. Decision Analysis, Technical Planning, Technical Assessment and Data Management scored slightly higher among Technical Management Processes. Anecdotal evidence also emphasized iterating prototype designs based on early customer feedback, focusing mostly on critical risks and holding more reviews early in a project schedule until a trust in the team is built.

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Lastly, I might have given up at different times if it wasn‘t for my best friend and future wife. Her constant support and frequent “status checks” helped me see this project through to the end.

Andrew R. Smith

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I. INTRODUCTION

The accelerated pace of change in the tactics, techniques and procedures used by adversaries of the United States has heightened the need for a rapid response to new threats. Fielding systems in response to urgent operational needs over the last half decade has revealed the DoD lacks the ability to rapidly field new capabilities for the warfighter in a systematic and effective way. – Report of the Defense Science Board Task Force on Fulfilling Urgent Operational Needs, July 2009

Background

The Department of Defense (DoD) acquisition system is chartered with providing effective, affordable, and timely systems to our operational forces (DoD 5000.01). From Los Angeles-class submarines to the M1A1 Abrams tank to the F-22 Raptor, the DoD has produced the most technologically advanced weapon systems ever made. With a workforce of 130,000 (OSD/AT&L, 2010), the acquisition community delivers the tools enabling our military to perform the missions they are tasked to accomplish.

The process by which we develop those warfighting tools has continually evolved to meet the changing times. A RAND study of acquisition reform (Hanks et al, 2005) lists major events in acquisition reform as shown in Table 1, to which this author has modified for brevity and included recent revisions to the DoD 5000 series of instruction that guides the execution of programs.

Table 1. Acquisition Reform Milestones

Date	Major Acquisition Event
1972	Commission on Government Procurement
1974	Office of Federal Procurement Policy Act
1982	Executive Order 12352 (established the FAR and directed procurement reforms)
1983	Grace Commission
1983	Office of Federal Procurement Policy Act
1984	Federal Acquisition Regulation (FAR)
1985	Department of Defense Procurement Reform Act
1986	Department of Defense Reorganization Act ("Goldwater-Nichols Act")
1986	Packard Commission
1990	Defense Acquisition Workforce Improvement Act
1993	Acquisition Law Advisory Panel
1993	Government Performance and Results Act
1994	Secretary of Defense Perry"s "Acquisition Reform: A Mandate for Change"
1994	DUSD for Acquisition Reform Office first established
1994	Federal Acquisition Streamlining Act (FASA)
1995	Commission on Defense Roles and Missions (CORM)
1996	Administrative Dispute Resolution Act
1996	Clinger-Cohen Act
1997	Defense Reform Act
1997	Quadrennial Defense Review #1, issued May 1997 (called for by FY95 NDAA)
1998	Acquisition Results Act
2001	DoD 5000 rewrite
2007	DoD 5000.01 Revised
2008	DoD 5000.02 Revised
2009	Weapon System Acquisition Reform Act (WSARA)

Currently, the United States is challenged in responding to new emerging threats, specifically in the proliferation of the improvised explosive device (IED). To complicate this threat, the enemy uses readily available commercial items and various explosive materials to build IEDs, combat tests hundreds of combinations of these devices aided by blending into the local population and by the covert nature of the devices, and communicates lessons learned and success stories across shadow websites on the Internet (JIEDDO, 2009).

The impact of our enemies‟ ability to produce weapon systems quicker, cheaper and within reach of our forces has lead to numerous studies on how to rapidly field new capabilities to the warfighter (DSB 2007, 2009; GAO 2010; Solomon, 2008). Anecdotal reviews of prior wartime acquisition offer the insight that it is possible to respond to emerging threats in a responsive manner to give our warfighters the advantage. Radar stations developed before and during WWII provided the British and Americans early warning for incoming German bombers (Brown, 1999). The Culin Hedgerow Cutter was adapted from steel obstacles (originally emplaced by the German army) and attached to the front of Sherman tanks allowing the breaching of hedgerows to counter German emplacements in confined fields in the taking of the French town of St. Lo (Guttman, 1998). Electronic countermeasures were implemented in F-100, F-105 and F-4 Wild Weasel squadrons to locate and negate surface-to-air (SAM) site threats during Vietnam (Hewitt, 1992). The United States military has a history of quickly implemented responses to emerging threats.

In fact, there are current efforts to provide our warfighters with timely solutions to their needs. The Defense Science Board identified no less than 20 groups dedicated to such a task (DSB, 2009). These organizations were found at many levels from the Office of the Secretary of Defense to the Major Commands (MAJCOMs) in the services to the Combatant Commands (COCOMs) themselves. Some were focused on a specific threat or capability, like the Joint IED Defeat Organization (JIEDDO) or the Intelligence, Surveillance and Reconnaissance (ISR) and Mine Resistant Ambush Protected (MRAP)

Task Forces, while others sought a way to handle the broader rapid fielding process, like the Rapid Reaction Technology Office or the Army Rapid Equipping Force.

Within the Air Force, the future technology capabilities are discovered, developed and delivered in the Air Force Research Laboratory. AFRL has aligned its programs along three Core Processes, each focused on the different stages from science studies to technology insertion. Core Process 3 (CP3) addresses the immediate needs requested by the warfighter and delivers a demonstration prototype within "12 months or less" (AFRL Instruction 90-104, Vol 3). While not fully matured along standard acquisition requirements, the prototype is expected to be used in the field upon completion of a successful demonstration. During the development effort, transition partners identify paths to insert the capability into programs of record, if desired.

Recently, AFRL issued an instruction for executing the CP3 mission. AFRLI 90-104, Vol 3, lays out general organization strategies such as forming "rapid reaction teams" and iNodes by matrixing subject matter experts from across AFRL, industry and academia to solve urgent needs. General guidance to meet timelines and frequent process owner updates combined with organizational "hard chargers" ensure prototypes are delivered on time. Currently there is no collection of lessons learned or best practices that would assist a program manager in creating a development strategy on short timeframes.

Previous studies have investigated 1) how DoD rapid development/ rapid acquisition organizations use innovation to meet urgent needs (Behm et al, 2009) and 2) how AFRL implements a systems engineering approach across all its programs to effectively deliver products to the acquisition community (Solomon, 2008). This effort will synthesize the two ideas to identify the systems engineering practices necessary for successful rapid development efforts within AFRL.

Problem Statement and Objective

Complex weapon systems require a level of organization to communicate designs, establish milestones and lay out a schedule. The field of systems engineering has developed a framework with a track record of helping programs stay on cost and on time (Honour, 2004). However, systems engineering (SE) is perceived in the science and technology (S&T) culture of AFRL as non-value added (Behm et al, 2009; Doyle, 2008). However, if a traditional SE approach can be tailored and validated for rapid development projects, this would be an approach well suited to meet user expectations by delivering quality products along aggressive schedules. The objective is to develop such a framework through literature review and validate by studying recent rapid development efforts in AFRL.

Research questions

1. What accepted activities in rapid development literature and practice correlate to Defense Acquisition SE activities?
2. What SE activities were emphasized by AFRL program managers, lead engineers and key personnel on recent rapid development projects?
3. How does the model reflecting the literature compare to the model found in AFRL rapid development projects?

Methodology

A review of literature will identify industry best practices for rapid development and systems engineering. Out of this review, a framework of key practices for rapid development will be derived from a comparison of current DoD suggested practices for systems engineering. A purposive sampling of AFRL rapid reaction team members will identify key SE activities utilized in recent projects and will be compared to the model formed by the literature study. Finally, a recommendation of best practices will be crafted for future AFRL CP3 projects conveyed in draft language for updates to the current AFRL Instruction 90-104, Volume 3, “AFRL Core Process 3, Innovative Solutions to Near-Term Needs”.

Summary

This chapter identified the need for rapid development and current challenges faced by the DoD. AFRL has instituted Core Process 3 to handle rapid development projects to meet urgent needs of the warfighter. Instituting best practices of successful rapid development projects within AFRL identified by literature review and validated with case studies will increase the success of CP3 projects. Chapter 2 will provide a literature review of the DoD‟s acquisition system, its efforts to meet urgent warfighter needs, and best practices of rapid development approaches in the academic and business literature. Chapter 3 will provide the methodology to determine a tailored systems engineering approach for CP3 projects within AFRL. Chapter 4 will compare the proposed framework with the case studies and present the results and assess the importance of SE activities in those case studies. Chapter 5 will then evaluate the framework and identify any possible improvements and conclude with a tailored SE model for rapid development projects conducted under AFRL‟s Core Process 3.

II. LITERATURE REVIEW

Current DoD Acquisition and Rapid Reaction Efforts

Formal Department of Defense acquisition processes and organizations have been slow and unresponsive to initial requests to counter the IED threat (DSB, 2009). The acquisition model currently used by the Department of Defense is based on three highly interrelated and complex processes to deliver weapon systems to our armed forces as outlined in the Defense Acquisition Guidebook- see Figure 1. The Joint Capabilities Integration and Development System (JCIDS) process identifies gaps in current warfighter capabilities and proposes solutions to fill those gaps. The Planning, Programming, Budgeting and Execution (PPBE) process makes the monetary and programmatic investments based on the prioritized list of gaps and solutions determined by the JCIDS process. The Defense Acquisition System executes programs based on the funding they receive to deliver a product to the warfighter.

The funding generally operates on a two year cycle and justification to the Joint Chiefs of Staff is generally required to make any major changes to the plan. The gaps discovered by the JCIDS process are initiated by requirements from the operational user who perceives a shortfall in capability of the equipment developed and procured for them. During wartime, solutions are needed much quicker than starting in the next two-year cycle. In response, many ad hoc organizations have sprung up and established organizations have developed new processes to meet the thousands of requirements, Joint and Urgent Operational Needs (JUONs and UONs) as defined in CJCS Instruction

3470.01, coming from combatant commanders. Figure 2 displays some of these organizations.

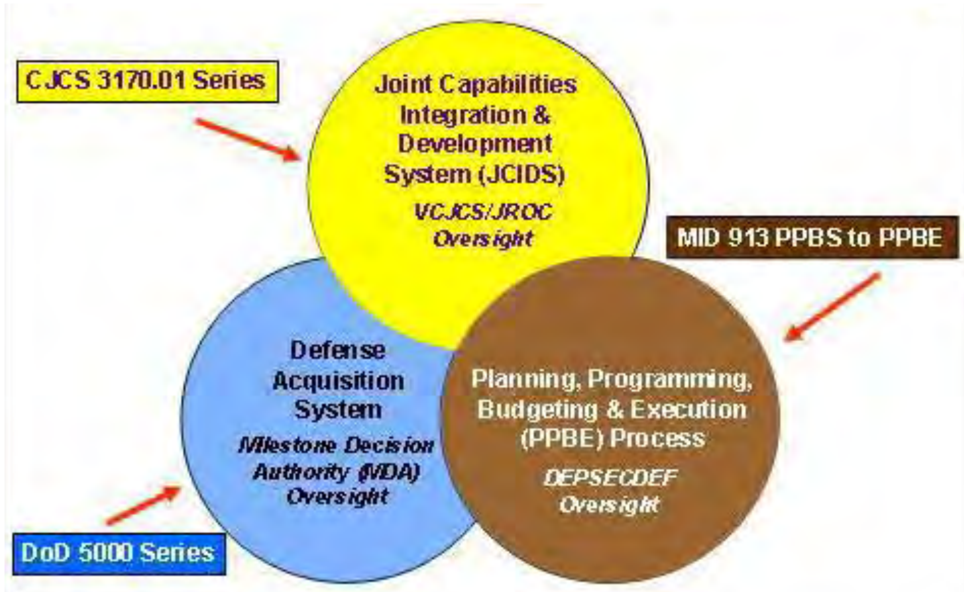

Figure 1: DoD Decision Support System (DAG, Ch1)

The Office of the Under Secretary of Defense has established the Joint Rapid Acquisition Cell (JRAC) to be the focal point for responding to JUONs. To manage COCOM requests that need a timely response, the DoD has created a subset of JUONs called Immediate Warfighter Needs (IWNs). These requests are designated by the JRAC as needing a material or logistic solution within 120 days. The JRAC then works with the appropriate service or organization to find a solution within 120 days, which if approved is delivered to the COCOM.

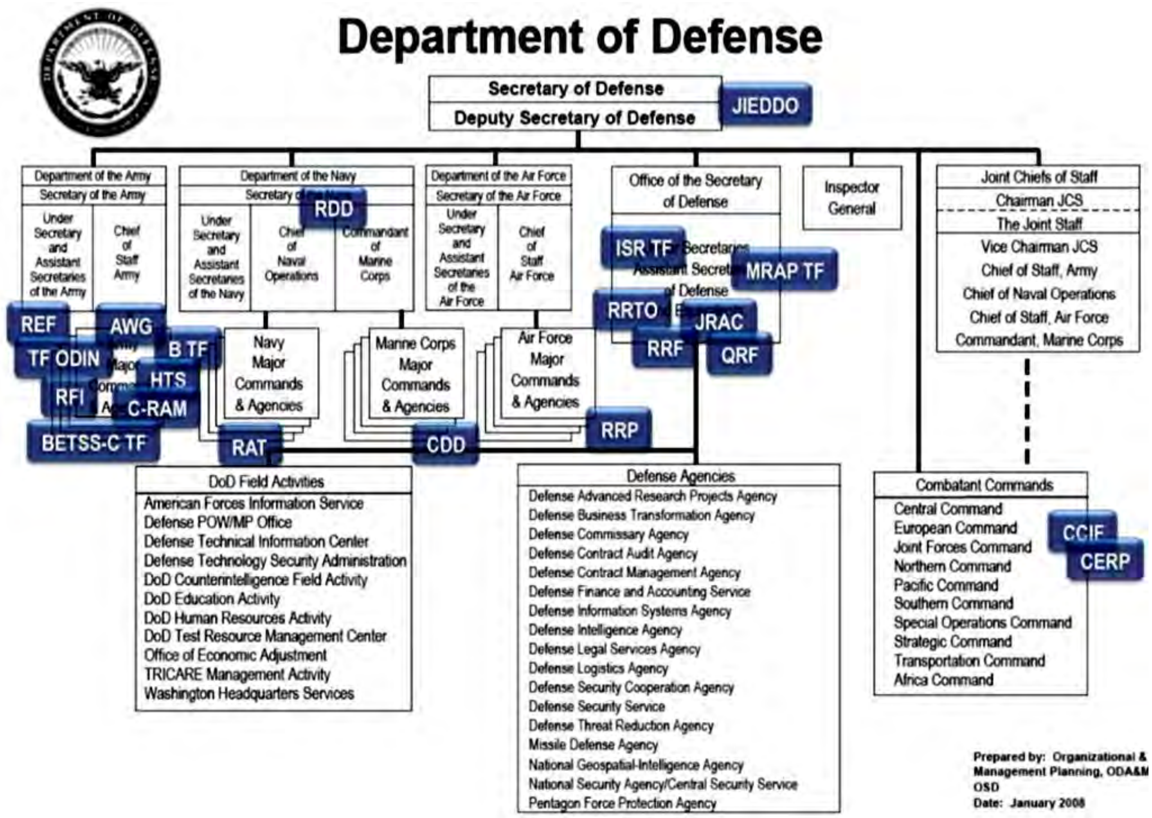

Figure 2: DoD Rapid Reaction Organizations (DSB, Urgent Needs, 2009)

The Air Force has established its own Rapid Response Process as codified in AFI 63-114. While oriented towards Air Force UONs, it has the capability to respond to JUONs if the solution resides within the Air Force Space and Missile System Center (AFSPC), the Air Force Materiel Command (AFMC), the Air Force Research Laboratory (AFRL) or the Program Executive Officers. The process starts with a COCOM submitting a UON to the lead MAJCOM (ACC, AMC, AFSOC, or AFSPC) which has the mission or capability shortfall addressed by the UON. A Combat Capability Document (CDD) may then be delivered to Headquarters Air Force for approval. This initiates the Rapid Response Process (RRP) which then reviews the CCD based on a set of criteria that includes timeliness of the solution, need of the capability to address the shortfall, whether the capability is “operationally safe, suitable and effective, supportive, sustainable, affordable with the support infrastructure already in place,” do not require RDT&E to field and that the CCD has addressed Mishap Prevention per AFI 91-202. If the CCD is approved without issues, HQAF is notified and the solution is implemented. If the CCD does not meet the RRP criteria, the lead MAJCOM may submit their request through the JCIDS process.

This emphasis on potentially lengthy upfront analysis and preparation has created a deterrent to pursue the RRP and incentive to find other means of answering the J/UONs. As described in CJCSI 3470.01 which addresses how JUONs are validated and funded,

> In most cases, the lead MAJCOM satisfies the combatant commander‟s urgent need through means other than the CCD process (non-materiel solution, internal programming authority, off-the-shelf purchase, etc.). This is the preferred method as it provides the quickest support to the warfighter.

In addition to the above instruction, recent discussions with HQ AFMC staff members validated the above statement by noting that no CCD has been written in the past year for submittal to the RRP.

It has been the personal experience of this author that in addition to the formal top-down flow of urgent needs, J/UONs are also created in a grassroots fashion. J/UONs are sometimes the product of warfighters connecting directly with product centers and technology experts. Once the need is expressed and a solution found, the J/UON is drafted and submitted through the formal channels and the solution is presented to the decision makers as an option. While not officially endorsed, it does have the benefit on reducing the time in discovering a solution.

AFRL has recently formalized a process to respond directly to urgent warfighter needs. To understand it in context an overview of AFRL is warranted. The official mission of AFRL is to discover, develop and deliver technology for insertion into the fighting force. It accomplishes this mission by three Core Processes. Core Process 1 (CP1) focuses on discovery and invests in basic research that the Air Force has determined will be needed to maintain superiority. Core Process 2 (CP2) matures and demonstrates applied research technologies that show potential for insertion into the inventory. Core Process 3 (CP3) has been established to meet urgent needs by providing direct communication between a Major Command (MAJCOM) or Combatant Command (COCOM) and the Lab to develop and demonstrate a solution within one year.

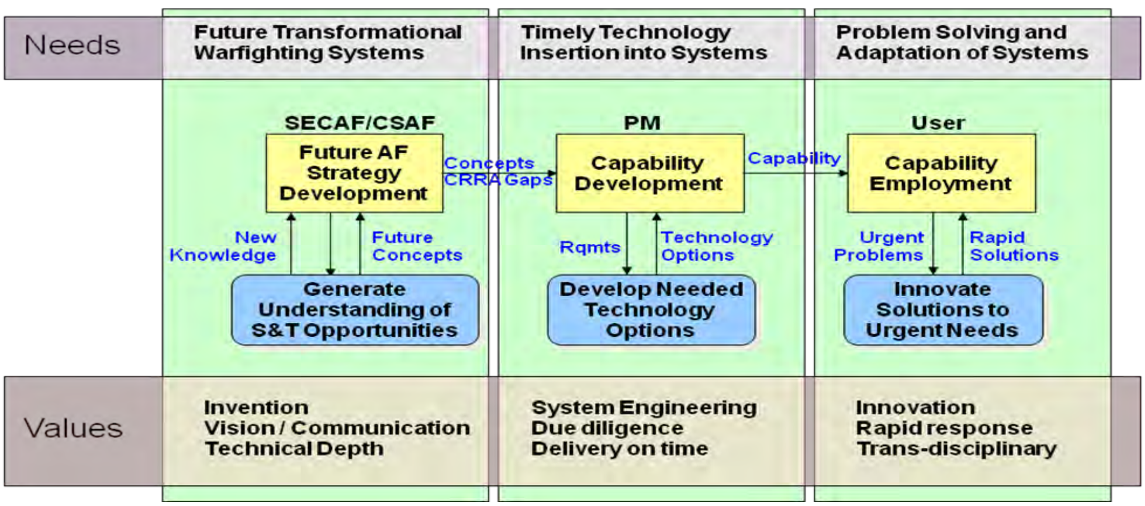

Figure 3: AFRL Core Processes (AFRL Overview, Lab 101)

A Core Process 3 project is loosely defined as capability that is intended to be fielded within two years. The project can either be initiated in two ways. “Technology push” efforts are considered by the AFRL Corporate Board and funded based on the perceived benefits of the proposed solution. “Requirements pull” projects allow a

MAJCOM or COCOM to directly request AFRL funding of solutions to urgent needs. Figure 4 illustrates that process.

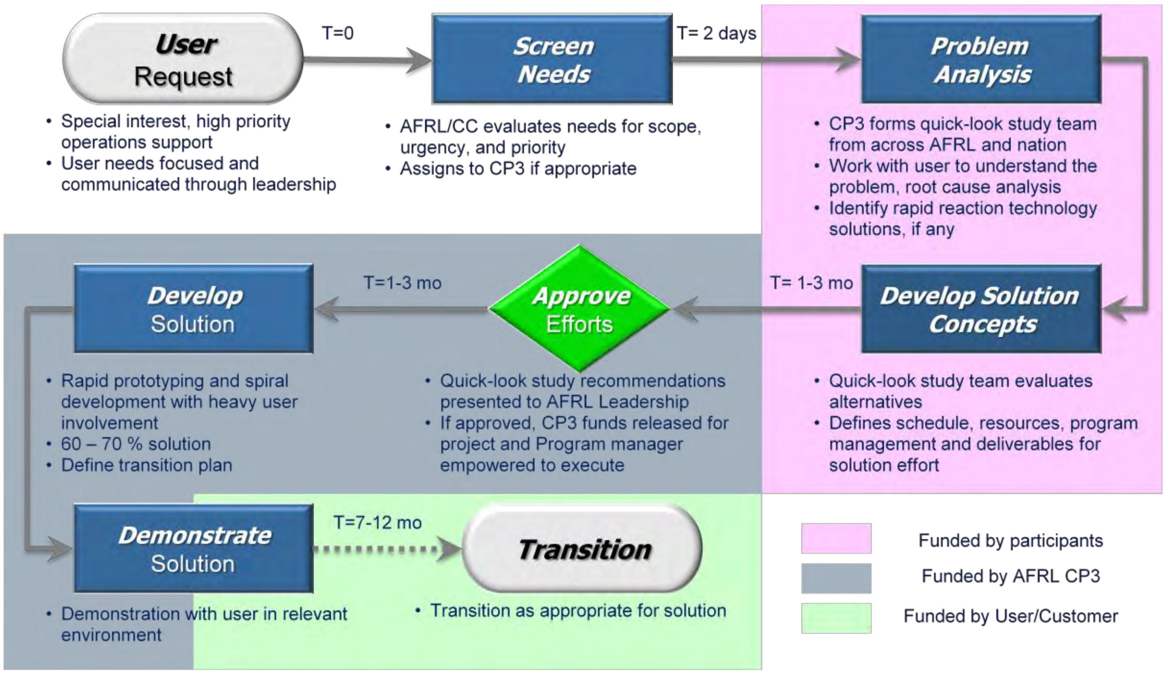

Figure 4: CP3 Requirements Pull Flowchart (CP3 Innovation and Collaboration, Lab 101)

Once the user has identified the need the request is communicated by the MAJCOM leadership (usually the first general officer in the user‟s chain). The request is sent to the AFRL commander for review and tags the request as a CP3 project. A 1-3 month study will define the problem as defined by the user, identify potential solutions and defines the timeline, cost and manning required to meet the request. The project is then reviewed by the AFRL commander and if approved, executed according to the proposal. A demonstration of the capability is set for 7-12 months from the initial request and, if it meets the user‟s requirements, is fielded. During this year, transition leads and paths are identified if the project warrants inclusion into a program of record (POR).

Currently there is no guidance on how to manage a CP3 program any differently from any other project in the Lab. Program managers are usually chosen due to excelling performance on previous projects and are typically “hard chargers” found in most organizations. Projects usually take on the personality of the program manager, or PM. While a “get it done” attitude helps in completing the paperwork necessary to start and run a project, there may be “blind spots” that PMs are missing that lead to inefficiencies, rework or not meeting schedules that are, by nature of the organization, aggressive. This study seeks to discover any blind spots and provide recommendations to support the program manager.

Prior Studies of Defense Rapid Development

A recent Defense Science Board (DSB) study on Fulfilling Urgent Operational Needs cited eight studies in the past five years that propose changes that would create an agile, responsive process for the DoD to rapidly field solutions to urgent needs. The common theme was that the current acquisition model does not satisfy the timeline of developing solutions to urgent needs because it focuses on “micromanaging risk and achieving the 100 percent solution” (DSB, 2009). While it might be tempting to use this as justification to abandon systems engineering principles to reduce timelines and “get it faster”, this impulse should be resisted. The fact is technical solutions are required to be *engineered* to fit within the larger military toolkit. Solutions must not work only in a vacuum.

The DSB also published a study establishing the Strategic Technology Vectors (DSB, 2007). A recommendation is made for a single Rapid Fielding Office to coordinate all rapid reaction organizations. This call is later echoed by the DSB Task Force on Fulfilling Urgent Needs with the proposal of the Rapid Acquisition Fielding Agency (DSB, 2009). One key recommendation in both reports is the use of systems engineering as a "cross-cutting enabler" that "manages the tradeoffs necessary to develop and field a system that is affordable, is sustainable, is delivered on schedule, satisfies user needs, and minimizes risk." (DSB, 2007)

The search, then, is to find the proper balance of SE practices implemented in a rapid reaction project. Two recent studies have independently addressed a tailored SE approach for AFRL and rapid development and acquisition. The 2009 AFIT thesis, "A Tailored Systems Engineering Framework for Science and Technology Projects," addressed a perceived disconnect between the conceptual framework of SE and its actual implementation in research projects. It produced a SE tool based on six discriminates: budget category, budget size, core process, technology readiness level, level of integration, and requirements maturity (i.e. requirements push or tech pull). The output of the tool when applied to a particular project was a level of "SE rigor" which placed each technical and technical management process into one of the following categories: Required, Recommended, Watch List, Not Applicable. It follows that this tool could be applied to rapid reaction projects.

In the 2008 AFIT thesis, "An Analysis of Methodologies and Best Practices for Rapidly Acquiring Technologies to Meet Urgent Warfighter Needs", Capt David Solomon studied the ways in which rapid reaction organizations foster innovation and how they utilize the "critical enablers" identified in the DSB Strategic Technology Vector study. As one of the enablers, systems engineering‟s perceived value varied across DoD rapid reaction organizations. Some respondents viewed it as vital while others saw no value. Nevertheless, one recommendation for future study was to investigate the appropriate amount of systems engineering and determine a tailored approach for projects that answer an urgent need.

Rapid Development Outside the Defense Department

Rapid development outside the military encompasses a few different areas. The field of prototyping deals with manufacturing a test product quickly. While the goal of this study is to shorten the time to deliver products, rapid prototyping focuses on the specific assembly of the product based on a complete design. Therefore the scope of this inquiry will extend beyond rapid prototyping. The field of software development also offers many methods to deliver products quickly. The attributes of software development lend to short time cycles from product design and integration to test and typically go through numerous iterations before a final product is delivered. While many of the urgent needs of the military tend towards hardware solutions, the lesson of understanding a problem and developing a solution is common to both cases. Finally, there exist studies in business management literature on how to shorten the cycle of product development. While the focus of these studies is to be first to market and being responsive to shifting consumer trends in order to maximize profitability, the methods uncovered will also be applicable since the goal of a short product cycle is common to both. Also, being first to market in the military sense equates to an advantage in technology or tactics for which the enemy hasn‟t developed countermeasures.

In 1991, James Martin wrote *Rapid Application Development* which sought to provide an alternative to "rigid" development methods, such as the waterfall method, to the software development community (Howard, 2002). In 1995, a group of software developers in the UK teamed with end-user organizations to create the Rapid Application Development (RAD) standard (Millington and Stapleton, 1995). The goal of the standard was to be a framework for vendors to follow when writing software applications. They listed five phases in the development life cycle. The first two focused on business matters, namely a feasibility report and a business study. The third phase focused on “functional model iteration, producing a functional prototype, a statement of non-functional requirements and an implementation strategy”. Following this was a “design-and-build iteration” where the prototype was tested against requirements. The authors suggest three iterations between the third and forth phases “for initial investigation, refinement, and consolidation.” Finally the system is implemented with the users with manuals and training.

While touted as a standard, RAD was more of a philosophy requiring autonomy and senior leader buy-in, experience and recognized talent among a stable team. In 2000, a case study was used to showcase RAD methods in an internal BT (formerly British Telecom) intranet project (Beynon-Davies, et al, 2000). In it, a matrixed team of employees was separated from their duty stations and tasked with building an internal on-line resource for their corporate relations department. In it the team delivers a working prototype in three weeks. While not being the final answer, the product allowed for future enhancement based on the potential of added requirements and was a complete product in that it met the requirements within the scope of the project.

A group at BAE Systems, Advanced Technology Centre, took RAD one step further in aggregating Extreme Programming (one of the different flavors of agile software development including RAD) and systems engineering (Jones and Leung, 2005). The objective was to build a wide area surveillance system that could be commercialized despite technical complexity. Their approach to the problem followed a three-point plan: 1) Define the CONOP to give a high level view of the system and provide scenarios for development and test. 2) Determine key questions in understanding the requirements. And 3) Develop a prototype system based on technologically mature components. The case study documents the development of a prototype system that through iterations from an initial system, meets the performance parameters established at the beginning of the project. Key, in the authors" minds, was the understanding of the component technology and the requirements of the system, both individual performance requirements and an understanding of the scenarios in which it was to perform.

In the world of business literature, a series of books written in the 1990s set the stage for companies to think about how they develop new products. In 1992, Wheelwright and Clark present "concepts for the effective organization and management of product and process development" in their book, *Revolutionizing Product Development*. Using case studies of Kodak, GE, Motorola and Lockheed they looked at project management frameworks in each company and identify five commonalities, namely "customer focus, discipline, coherence, fit and sharing the pattern." Customer focus sought to understand the user"s requirements but also their unmet needs. A contemporary case in the consumer electronics market would be Apple"s success with the iPod. In the military sense, this can be seen as understanding the capability gap beyond what the user states as requirements. "What aspect of their mission is not being met that they don"t know yet?" Discipline is geared towards a streamlined process that fosters "thoroughness and consistency" but doesn‟t “stifle creativity” or slow down projects with unnecessary oversight. Coherence deals with assigning the right skills to projects not only in a technical sense but also a managerial approach. Fit with the mission ensures that the solutions of a project match the stated objectives; for example, technical solutions to solve technical problems rather than manufacturing or personnel issues. Finally, sharing the pattern looks at how organizations communicate a common framework and set expectations of “what must be done, when and how.”

Focusing on the “discipline” aspect, Wheelwright and Clark devote Chapter 9 to “Tools and Methods” for executing projects. After proposing strategies for meeting performance goals and laying out effective plans, making sure the right people understand the right processes, the authors focus in on problem solving at the working level. Cross-functional teams meeting with each other to “solve specific problems.” In their study, the ability to solve problems was at the heart of good product development. Their method for consistent, quality problem solving is broken down into the “design-build-test cycle”. Similar to the Vee Model in the Systems Engineering Handbook (INCOSE, 2003), Wheelwright and Clark‟s model is straightforward. In the design phase, requirements and tradeoffs are explored with clear objectives and alternative solutions are generated. The build phase then acts on those designs whether producing CAD models or test code or other engineering prototypes. The test phase then executes a test plan based on collecting the right information accurately in an environment as close as possible to the intended use environment. Wheelwright and Clark also encourage the use of iterations if the first cycle fails to meet the expected performance measures.

In 1993, in the second edition of his book, *Winning at New Products: Accelerating the Process from Idea to Launch,* Robert Cooper proposed Stage-Gates as a method to develop new products. Similar to the Defense acquisition milestones, Stage-Gates take an idea through a series of gates to determine if the idea is worth committing resources to go to the next stage. The five stages, being Preliminary Design, Business Case, Development, Testing and Validation, Full Product & Market Launch, all have entrance and exit criteria and allow a team to focus on each phase before proceeding to the next. One caution from the author is that it is intended that the process not focus on one functional area per stage, but rather use multi-functional teams to work in parallel through the stages. For instance, a test team member might have valuable insight on creating a testable specification during the preliminary design phase that will shorten test time down the road or a marketing team member may use validation results that would target key early adopters in winning early critiques of the product. Stage-Gates are not intended to be inflexible and companies are encouraged to tailor them to suit different project category needs. The process should enable teams to create the right product efficiently, not enable management to become roadblocks.

For the purposes of this research, the reader should assume that the project idea has been identified, the business case has been pitched and management has agreed to initiate the project. This starts the project in Stage 3, Development. The first action Cooper suggests is to confirm the requirements. Bring users in to expose any incorrect assumptions or to re-prioritize the performance targets in case there were shifts in the marketplace (analogous to threats and capability gaps in the military). A development plan is then built with tasks listed, realistic timelines to complete and resources assigned. Additionally, milestones throughout the project with definable goals for the development set targets that team members can agree on and plan activities accordingly. Throughout the development stage, in-house testing is iterative and customer involvement and feedback is essential in creating the right product. Cooper"s Stage 4 encompasses preference tests ("do I like your product better than what I have") and field trials (limited quantities or simulations to gauge user interest) are analogous to the DoD"s operational testing. In each case, the product is tested in a relevant environment with representative users to validate the product and collect feedback before full-rate production.

Five years later in 1998, the second edition of Preston Smith and Donald Reinersten"s book, *Developing Products in Half the Time: New Rules, New Tools* was published. Smith and Reinertsen pick up on the ideas of the two prior authors and offer a few of new concepts such as the "fuzzy front end" which they define as the time from when an opportunity is discovered to when a development team begins work on the project. Some of this time is due to the bureaucratic nature of organizations but also includes factors such as expedited shipping costs that may be reduced if identified earlier in the project timeline. As an improvement to Cooper"s Stage-Gate style of phased project planning, Smith and Reinertsen suggest product development organizations reduce the emphasis on the gates (i.e. less formal reviews) and more emphasis on the flow of the project. For example, management may decide exit criteria for each stage and let the team decide when they have met those criteria. Reports could be presented at quarterly reviews (or more frequent) to ensure projects don"t run amok.

In separate sections, Smith and Reinertsen address managing risk. In the first, technical risk is addressed by focusing risk mitigation within individual models of a design versus distributing risk management broadly over the whole. System integration risk is reduced by focusing on the riskiest modules and the use of margins or safety factors for critical items such as fastener tolerances. In the second section (Chapter 12), the authors re-address technical risk and compare its relation to market risk. Too much technical risk management, in the form of multiple reviews, can increase market risk by delaying a project introducing uncertainty into sales predictions. Of course, not enough technical risk management results in costly surprises late in the development cycle. Smith and Reinertsen suggest that it depends on the project goals and a moderate level of risk management leads to shorter development cycle times. To control risk, the authors offer a commonly used chart where the probability of an event (i.e. assembly of the engineering prototypes) is compared with the impact of it not happening (i.e. field tests slip 1 month) as shown in Table 2. Events that are likely to occur with a high impact on schedule, say, are identified as high risk.

Table 2: Risk Analysis Table

Consequence of Risk	High Impact			
	Med Impact			
	Low Impact			
		Low	Med	High
		Probability of Occurrence		

In 2007, Michael Grieves wrote *Product Lifecycle Development* based on his background in the automotive and IT industries. While not specifically focused on “rapid development”, Grieves notes that cycle times are an external driver pushed by customers and competition and provides examples of multiple industries that exhibit this phenomenon from the automobile to fashion to pharmaceuticals. His describes the five functional areas of product lifecycles as “plan, design, build, support, dispose.” The planning consists of “requirements analysis and planning” which leads into the design phase where engineers play with trade-offs while ensuring the requirements are met. Prototypes are then built based on specifications that ensure the “various components fit together in an integrated system and that the system is internally consistent.” During the build phase, manufacturing engineers decide how the product is built and in what steps. Finally the support and disposal ensure feedback is attained from the customer and decisions are made concerning what to do with it after its use.

Finally, the Product Development and Management Association (PDMA) has published a collection of tools “most appropriate for use in the engineering design and development phases” of new product development in *The PDMA Toolbook 3 for New Product Development*. Released in 2007, *PDMA Toolbook* covers multiple topics from trade-off analysis to intellectual property to development. Gregory Githens offers the Rolling Wave approach to development cycles. In traditional projects, a schedule is built and tasks are populated from beginning to end on the assumption that all actions required are “knowable” upfront. The Rolling Wave approach seeks to create a “robust“ schedule that is flexible and overcomes “brittle schedules” that occur when early slips lead to “individuals [that] narrow their focus to their own subjective view of priorities”.

The proposed solution seeks a “plan-do-plan-do” series of activities where segments of the project are broken up into “rough order magnitudes” or “ROMs”. Tasks are only planned out as the team reaches each ROM Group. The argument goes that task completion dates grow in uncertainty the farther away they are. Therefore, focusing on short-term forecasts will produce more reliable estimates in the long run. Githens emphasizes that agility both in the product and project architecture. Product agility covers interface management and the use of common technical standards. Project agility concerns team composition, levels of authority, review and approval cycles, roles and responsibilities, risk and issues analysis, escalation strategy, etc." Githens then offers six steps in executing a Rolling Wave approach as shown in Figure 5.

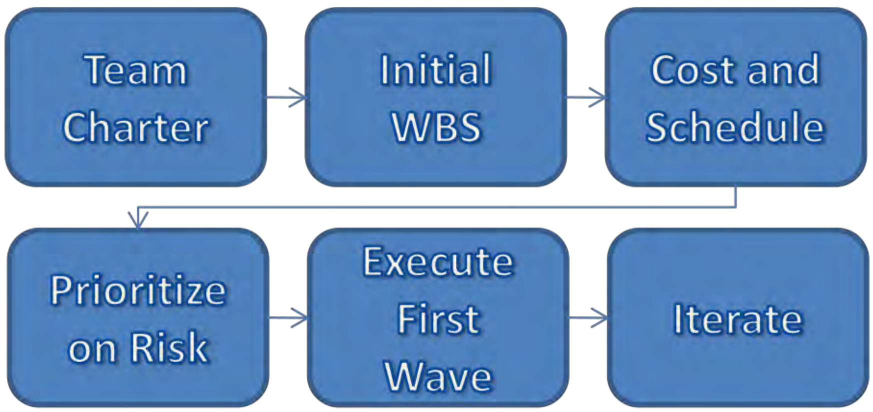

Figure 5: Rolling Wave Methodology

Step 1 starts with a team charter that captures the requirements management, team roles and responsibilities and lays out the vision of the project. Step 2 is creating a work breakdown structure (WBS) to include Level 1 and Level 2 activities. Level 1 will be segmented by the ROM Groups or "planning windows". Tasks that are well understood and can be detailed to the work package level are documented in the WBS while less certain tasks, say specifications that require user feedback on prototypes, are left undefined and assigned to later planning windows. Step 3 details the tasks of the WBS for each and starts the "plan a little" stage. Cost and schedules are presented as range estimates that can be as little as half the target or as much as twice the target. This requires project managers to gain the trust of stakeholders to allow the flexibility of this planning approach. Additionally, a transition plan should be formulated to prevent delays at the end of development and the beginning of product launch or delivery. Step 4 proposes managing risk and reprioritizing activities versus establishing a baseline and monitoring variance. Step 5 executes the first ROM Group or “do a little” with attention paid to monitoring risks and keeping key stakeholders up to date if cost or schedule variances break a predetermined threshold. Step 6 iterates the planning-doing cycles until completion. The key activities are assessing the groups‟ progress, anticipating tasks in future planning windows and ensuring the “big picture” is fixed in each team members‟ decision making processes.

Summary

This chapter presented an overview of rapid development efforts within the DoD, the USAF and AFRL. In addition it looked to industry for additional frameworks for rapid development. These and other methods from literature will be compiled and consolidated in Chapter 3. The common processes will be translated into the SE technical and technical management processes to take advantage of acquisition training required for certification in the acquisition career field. A purposive sampling of AFRL rapid development team members will identify the methods currently used in the CP3 organization.

III. METHODOLOGY

Introduction

A mixture of qualitative and quantitative methods will be used to assess the relative importance of various processes and artifacts defined in Chapter 4, Systems Engineering, of the Defense Acquisition Guidebook (DAG) with respect to rapid development projects. Terms referenced in the definitions of each process will be compared with those found in the literature and evaluated based on importance. A management strategy will then be proposed based on the relative importance of each process. A comparison with key activities identified by a purposive sampling of AFRL rapid development team members will provide an evaluation of the proposed strategy compared to recent projects.

With origins in the product development community, methodologies such as Stage Gating, Product Lifecycle Management and Rapid Application Development offer strategies to apply to rapid development. Identifying key processes in these methods will be compared to the 8 technical and 8 technical management processes as defined in the DAG.

Product Development Literature Evaluation

Content analysis is a method that has origins in the 1940s and began with conducting word counts on texts. Eventually it matured to concepts and meanings. A conceptual analysis is a sub-category of content analysis where texts are examined for frequency of words or phrases related to a research question. In this study, product development texts will be examined for the frequency of SE keywords determined by this author from the DAG SE process definitions. The relative frequency of these keywords will provide insight as to what the authors deem important in instructing the reader how to do product development. A listing of keywords for the technical management and technical processes can be found in Tables 4 and 5, respectively.

Processes will be identified and assessed in each literature method based on their importance. Importance in this case will be equated with frequency. The number of references to keywords from the DAG SE process definitions will be normalized and assigned an importance score ranging from 1- Not Important to 5- Extremely Important as seen in Table 5. Keywords are listed in Tables 4 and 5, respectively. The reader is referred to the DAG, Chapter 4, section 4.2.3, for complete definitions of each technical and technical management process.

Table 3: Keywords of the Technical Management Processes

Technical Management Process	Keywords
Decision Analysis (DA)	Trade Studies, Analyses- Alternatives, Supportability, Cost, Trade Off
Technical Planning (TP)	Scope of Technical Effort, Systems Engineering Plan
Technical Assessment (TA)	Technical Review, Program Review, Technical Interchange, Interface Control Working Group
Requirements Management (Req Mgmt)	Requirements, Traceability, Change Management
Risk Management	Risk- Identification, Analysis, Mitigation, Tracking
Configuration Management (Config Mgmt)	Technical Baseline, Functional Baseline, Allocated Baseline, Product Baseline, Change Management, Audits
Data Management	Technical Data, Records, Organization, Sharing
Interface Management (Int Mgmt)	Interface Specifications, Standards, Compliance

Table 4: Keywords of the Technical Processes

Technical Process	Keywords
Stakeholders Requirements Definition (SRD)	Requirements, CONOPS, Constraints, Stakeholder
Requirements Analysis (RA)	Functional Analysis, Performance Requirements, Functional Architecture
Architecture Design (AD)	Design Solutions, Logical Models or Views, Physical Architecture, Specification
Implementation (Imp)	System Elements, Production, Component Testing
Integration (Int)	Assembly, Interfaces, Incorporation, Prototype
Verification (Ver)	Demonstration, Inspection, Analysis, Test
Validation (Val)	Validation, Evaluation
Transition (Trans)	Installation, Integration, Fielding

Table 5: Importance Scale Descriptions

Importance Scale	Description
0-1	Not Important
1-2	Somewhat Important
2-3	Important
3-4	Very Important
4-5	Extremely Important

Proposed Framework

A comparison of each method against the 16 system engineering processes endorsed by Chapter 4 of the DAG will highlight where emphasis has been given by the authors. Keywords will be counted for frequency within the books and texts to indicate importance and normalized to provide comparable values. Normalized scores are calculated by the equation:

$$Score_{normal} = \frac{Score_i}{MAX(Score_i)} \times 5,$$

Where $Score_i$ is the number of keyword references from each author for a process, i, $MAX(Score_i)$ is the maximum number of references from each author in a particular process and multiplied by 5 to fit the scale in Table 5. This will normalize the scores to show which is process is most emphasized which will be equated with most important. The scores for the technical management and the technical processes will be normalized separately since technical processes typically take place sequentially and technical management processes occur throughout the life of a project. Scores will then be totaled and calculated as a percentage to display relative weights to which program managers can allocate resources (time, money, and people).

Purposive Sampling and Analysis

This study will follow a similar methodology conducted by a recent INCOSE paper (Mulhearn and Brouse, 2011). In it, the authors investigate small information technology (IT) projects with the intent of filtering the most important documents to "effectively and efficiently manage the project". Twelve knowledge areas were combined from ontologies from both the program management and systems engineering literature to encompass the technical emphasis of the IT projects. "Small" IT projects were defined as "under 12 months in duration and cost less than $1.5M." A survey sent to a purposive sampling of IT professionals identified the top 15% of documents and reviews. It is the intent of this review to conduct the same evaluation with AFRL program managers for rapid reaction projects.

Interviews with key personnel (program managers and chief engineers) on rapid development projects will provide an evaluation of the current emphasis placed on each process. Each process will be assessed by the author on a 1-5 scale of importance. The criteria are derived from SE technical process outputs as outlined in the INCOSE Systems Engineering Handbook, v3.1. These definitions were chosen over standard DoD Acquisition terminology to encompass activities that met the intent but weren‟t specifically defined by DoD terms. Some criteria were augmented by DoD Developmental and Operational Test activities where the INCOSE SE handbook provided insufficient measures to stratify the formality of a particular process (i.e. Verification and Validation). A listing of interview questions and topics is found in Appendix A. These scores will then be compared with the model determined by the product development literature.

IV. DATA ANALYSIS

Overview

This chapter will present the results of the conceptual analysis of the product development literature with respect to DAG SE processes. From this analysis, an allocation of resources will be presented by looking at the relative scores of each process. The chapter will then present the results of the levels of formality of SE processes uncovered in the case studies. Finally, the two levels of importance will be compared with each other and analyzed.

Results

Tables 11 and 12 show the normalized scores of the SE processes found in each rapid development approach. Figures 6 and 7 display this data as bar charts, with the standard deviation computed for the error bars. Based on the data, the most important Technical Management processes for rapid development are Technical Planning, Decision Analysis, Risk Management and Technical Assessment. There is a general concurrence that Technical Planning is a must for product development as this process has the highest score with one of the smallest deviations. All other Technical Management data show a mixed emphasis for each of the other processes. Decision Analysis, Technical Assessment, Risk Management are slightly more emphasized while Requirements Management, Configuration Management and Data Management slightly less and Interface Management almost not at all.

The most important Technical Processes are Stakeholder Requirements Definition, Architecture Design and Integration. There is a concurrence that Stakeholder Requirements

Definition is emphasized heavily while Architecture Design, Integration and Verification are emphasized slightly more and Validation slightly less. Requirements Analysis, Implementation and Transition received low scores having not been emphasized in the texts.

Table 6: SE Technical Management Process Scores

Technical Management Processes	DA	TP	TA	Req Mgt	Risk Mgt	Config Mgt	Data Mgt	I/F Mgt
Wheelright and Clark	2.50	5.00	1.50	0.50	1.00	0.00	0.00	0.00
Cooper/ Stage Gates	4.17	5.00	3.33	0.00	3.33	0.00	0.00	0.00
Smith and Reinertsen	2.14	5.00	1.43	1.43	5.00	1.43	1.43	0.71
PLD	1.25	3.75	0.00	1.25	0.00	3.75	5.00	0.00
RAD	1.67	5.00	1.67	3.33	1.67	3.33	3.33	0.00
PDMA	4.38	4.38	5.00	0.63	3.13	0.63	0.63	0.63
AVERAGE	2.68	4.69	2.15	1.19	2.35	1.52	1.73	0.22
St Dev	1.30	0.52	1.75	1.17	1.81	1.65	2.03	0.35

Table 7: SE Technical Process Scores

Technical Processes	SRD	RA	AD	Imp	Int	Ver	Val	Tran s
Wheelright and Clark	5.00	1.67	3.33	1.67	2.92	2.50	2.50	0.00
Cooper/ Stage Gates	5.00	0.56	1.67	0.56	1.11	2.22	1.67	1.11
Smith and Reinertsen	2.22	1.11	5.00	0.00	1.67	0.56	0.00	0.56
PLD	3.75	1.25	3.75	0.00	5.00	2.50	1.25	0.00
RAD	5.00	1.67	1.67	0.00	1.67	3.33	1.67	0.83
PDMA	5.00	0.34	0.86	0.17	0.34	0.34	0.34	0.52
Average	4.33	1.10	2.71	0.40	2.12	1.91	1.24	0.50
St Dev	1.15	0.55	1.57	0.66	1.64	1.19	0.93	0.44

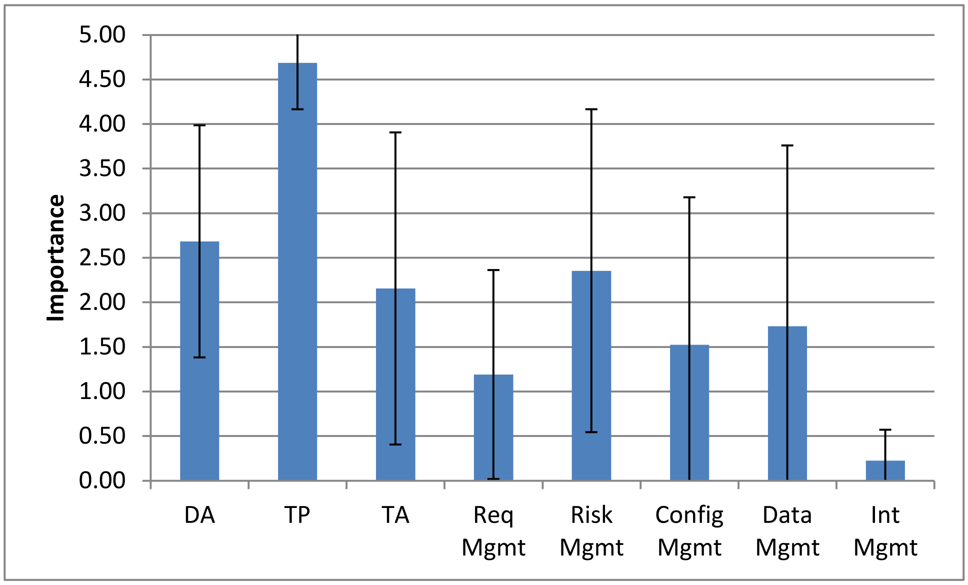

Figure 6: Technical Management Process Scores with Standard Deviation Error

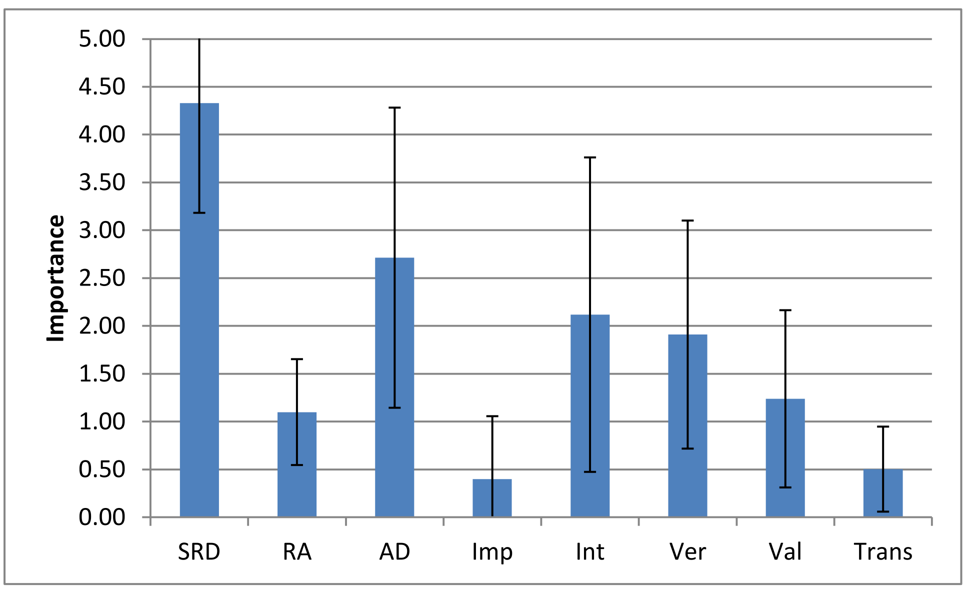

Figure 7: Technical Process Scores with Standard Deviation Error

Analysis

From the emphasis the literature places on the technical management processes, the project manager must first manage the scope and develop the technical plan for achieving the project objectives. This is a logical conclusion since vague requirements or a lack of technical direction can lead to miscommunication or mismanaged expectations which can lead to rework or product rejection. This does not mean that the initial scope or technical plan must change, rather that the project manager must manage how potential changes affect the development of the end product. Once the technical planning process is in place, the project manager must support it with Decision Analysis, Technical Assessments and Risk Management. In other words, to direct the technical effort a project manager must understand the performance and cost trade-offs of different approaches, assess the progress throughout the development and have a robust risk management procedure- identify, assess, mitigate, track- to deal with problems before they come to bear. Requirements Management, Configuration Management, Data Management and Interface Management are all things a project manager should be mindful of, however, they should not take a majority of his/her time and resources.

The Technical Management scores generally follow the “Design- Build- Test Cycle” put forward by Wheelright and Clark. Stakeholder Requirements Definition was clearly the most important which is logical since new products are developed to meet a need, whether a perceived need in the commercial industry or a stated need in the defense acquisition system. A project manager must understand how the new product is intended to perform, in what environment, how it interacts with other systems and so on. Architecture Design followed next with a physical solution to meet the requirements. Having CAD models and logical views, such as the DoDAF Architecture, ensures that the team is "on the same page" for designing the system. Integration and Verification were next in importance showing that it is important to put the components together correctly and test the system to ensure it was built right.

The lower Technical Management process scores could be explained as an outcome of focusing on the higher scored processes. For example, if a project clearly defines the outputs of the Stakeholder Requirements Definition process- namely the CONOPS, environment, constraints as stated by all the stakeholders- the Validation testing should be easier and thus less emphasized. If the Architecture Design is correct, then the Implementation of building the components to the design specifications should be well understood and less emphasized. If the right product is built correctly, then Transition should follow without major problems. The score for Requirements Analysis however seems out of place. This result could be explained by its dependence on a successful Stakeholder Requirements Definition phase, but it is also conceivable that the keywords chosen were an inaccurate measure of the process or that the keywords exist primarily within the systems engineering community or specific to DoD SE that the authors of the texts under study did not use this terminology.

By converting the scores to an overall percentage, as shown in Figures 8 and 9, a program manager can weigh each process relative to the other and plan out a project. Since these are process resource allocations it makes more sense to apply these percentages to the management of a project and not the overall budget, which could include high-cost items. It can be helpful to think of applying the percentages to the time allotted during regular meetings or hours in a week that a project manager focuses his/her time directing the project.

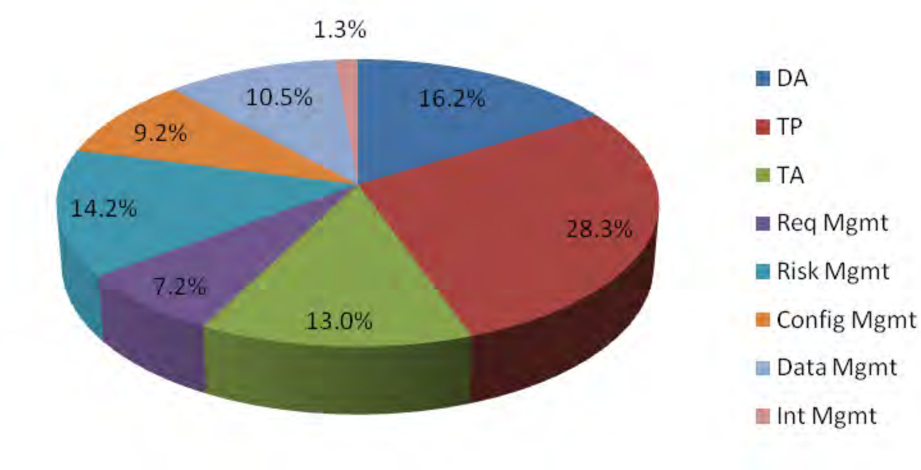

Figure 8: Technical Management Process Resource Allocation

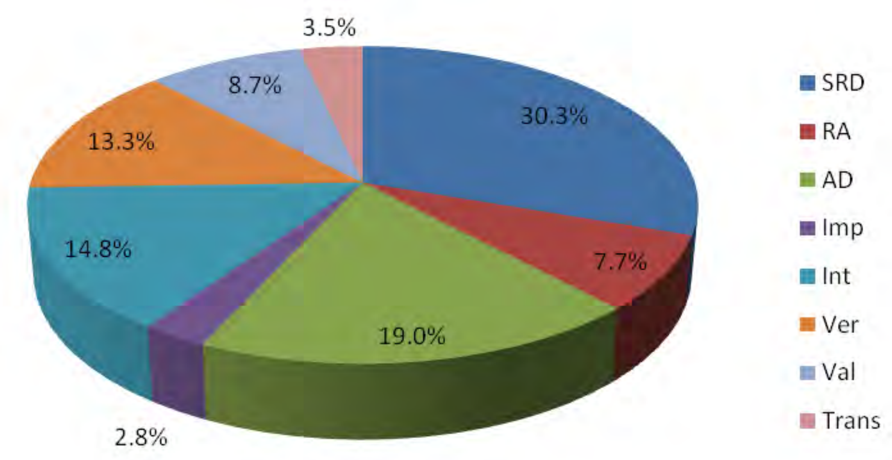

Figure 9: Technical Process Resource Allocation

One concept not captured in evaluating the different processes was iteration. Most of the texts cited process iteration as a key strategy in product development. Once a design is created, it is presented to the stakeholders for feedback and refinement. This could happen multiple times but the Rapid Application Development team suggests at least three iterations. The inability of this evaluation to capture the importance of design iteration could give program managers a false impression that a single pass development strategy using the above resource allocations will produce a successful product. A more successful strategy is to integrate the user into the development team providing constant feedback as the product grows from requirements to specifications to assembly and test.

Key Activities Identified by AFRL Rapid Reaction Team Members

A purposive sampling was conducted between AFRL Scientist and Engineer (S&E) employees that have participated in Core Process 3 (CP3) projects. Individual interviews sought to establish a baseline of common practices for project managers. The interviews were conducted among engineers and program managers with 2-6 years of experience in AFRL rapid development with projects ranging from 6 months to 3 years in schedule and $500,000 to $12M in budget. Backgrounds ranged from prior military service to active duty to career civilian with positions in and outside of AFRL. Team sizes for their rapid development projects ranged from 3 to 12 people.

For each technical and technical management process, a common set of products (i.e. work breakdown structure, integrated master plan, team charter, key resources for Technical Planning) was evaluated for whether the subject fully, partially or did not accomplish during their projects. (A full list of the common products can be found in Appendix A.) The author infers from this assessment that the effort put to creating (or not creating) these products reflects a level of importance the subject placed on each technical and technical management process. These scores will be compared with the literature review scores and analyzed in Chapter 5.

Figures 10 and 11 show the results from the interviews. The scores are on the same scale of level of importance (1 to 5) and reflect what project managers have done. The technical process scores at first glance do not present any "smoking guns". Architecture Design and Implementation show slightly higher scores while Verification, Validation and Transition show slightly lower. Since rapid development projects are by nature short on schedule, little slack is built in and thus an emphasis on doing more up front is displayed in the data. Subjects noted using engineering standards and monitoring progress to identify opportunities as ways to stay within short timelines.

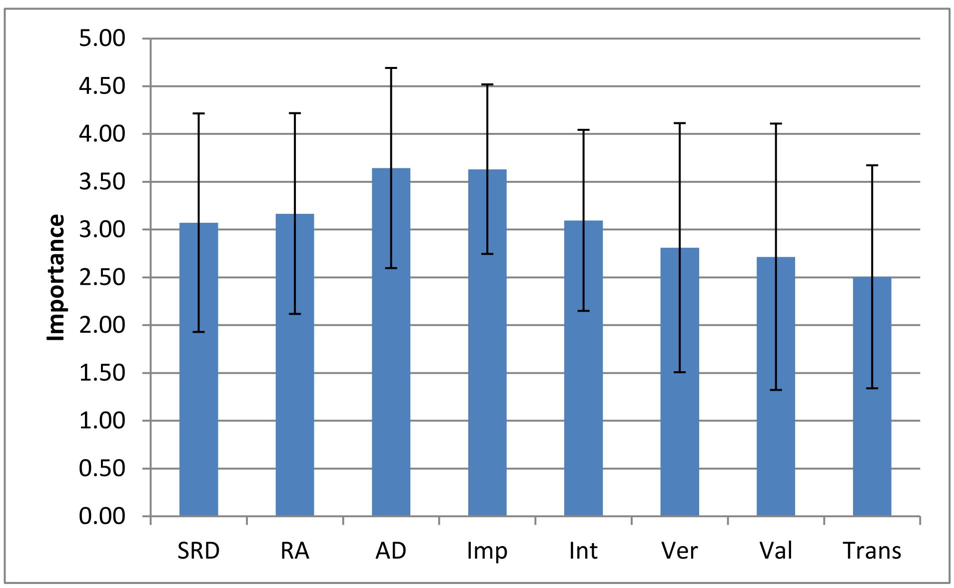

Figure 10: AFRL Rapid Development Technical Process Scores

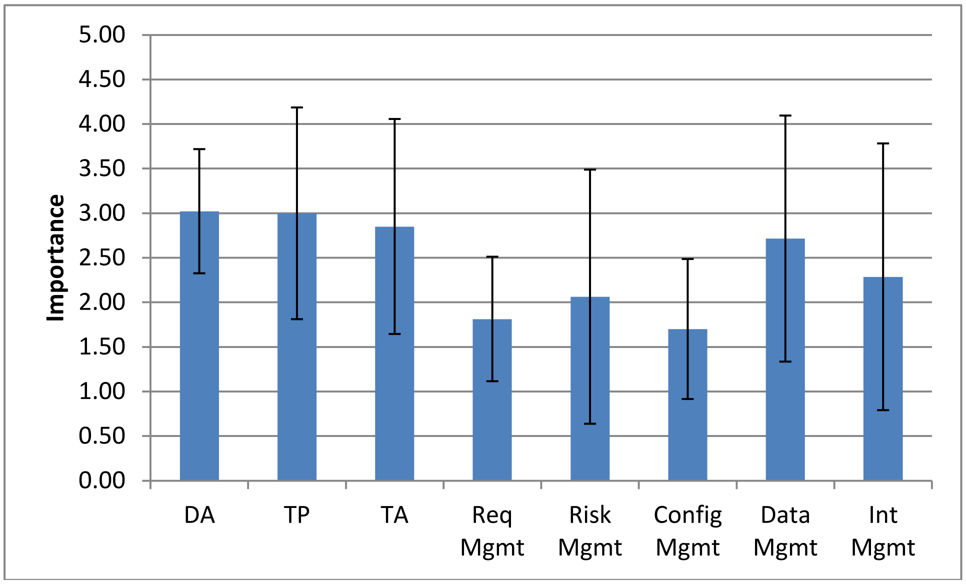

Figure 11: AFRL Rapid Development Technical Management Scores

The technical management processes, however, show greater variability. Decision Analysis, Technical Planning, Technical Assessments and Data Management all have higher scores than Requirements, Risk, Configuration and Interface Management. During interviews, it was commented that rapid development projects require strong leadership, delegation to the most competent team members, and emphasizing sharing information over documentation as successful strategies during rapid development projects. These themes reflect the first three processes listed. The last process, Data Management, may have scored higher due to the complex technical nature of the projects.

Many interviewees had comments that could not be captured by the survey on how they do rapid development. The following statements were from individuals and not themes expressed by multiple people. One interviewee likened rapid development to a "jazz [band], not an orchestra." Another noted that he would have more "Interim Program Reviews" with newer teams to build up the trust in the group and cut back once the team was performing at a sufficient level. His advice on time management was to "identify the most critical risks" to the project weekly and mitigate during hour-long conference calls and that rapid development "required strong leadership." The smaller risks were often left to individual team members, allowing the more senior team members to focus on the hard problems. Another interviewee said he didn‟t receive enough training on risk management when applied to rapid development. One suggested that you don‟t use Microsoft Project and that schedules don‟t show activities finer than one week.

One interviewee felt the current project milestones weren‟t chosen without monitoring a project, but rather were held based on the initial schedule. He felt that reviews were being held to catch problems and that issues "should be caught before test reviews". When applied to software, he felt that rapid development didn‟t afford time to check bugs in code written by geographically separated programmers, that there "wasn‟t time for QA [quality control].

V. DISCUSSION

Overview

This study set out to identify key processes within the Department of Defense Systems Engineering framework that were of importance to rapid development projects within AFRL. A content analysis of product development literature, where industry strives to be the first to market a quality product, was performed across six different sources representing various communities in product development- academia, consultancy, software, trade association- and across 15 years of research. The frequency of keywords derived from the DAG definitions of each project was used to infer an importance emphasized by each of the texts. By computing a relative score on a scale of 1 to 5, certain processes were shown to be more important in product development. Technical Planning stood out as the most important Technical Management process followed by Decision Analysis, Technical Assessment and Risk Management. Stakeholders Requirements definition showed to be the most important Technical Process with Architecture Design, Integration and Verification

A purposive sampling of AFRL S&E employees was conducted to evaluate the current implementation of SE processes within rapid development projects. Interviewees were asked to describe their approach to projects they had participated in or led. The author evaluated their responses with a numerical score based on how fully different SE products were created and thus their importance inferred. While the technical processes showed relatively similar results, Architecture Design and Implementation were scored slightly higher. This has been attributed to the short schedules of rapid development forcing more emphasis "up front". Technical management processes that scored higher included Decision Analysis, Technical Planning and Assessment, and Data Management. The theme here is that a strong decision making framework (or strong leadership) is useful to keep skilled teams on schedule during technically complex projects.

When combined, the content analysis and purposive sampling offer an interesting comparison. Figures 12 and 13 show both sets of scores for the SE processes. First, we‵ll examine the technical process scores. While both sets of data agree that Architecture Design is important, the literature does not emphasize Requirements Analysis (RA) nor Implementation to the same degree that the AFRL S&E‵s place importance on those processes. The literature does, however, place a large emphasis on Stakeholders Requirements‵ Definition.

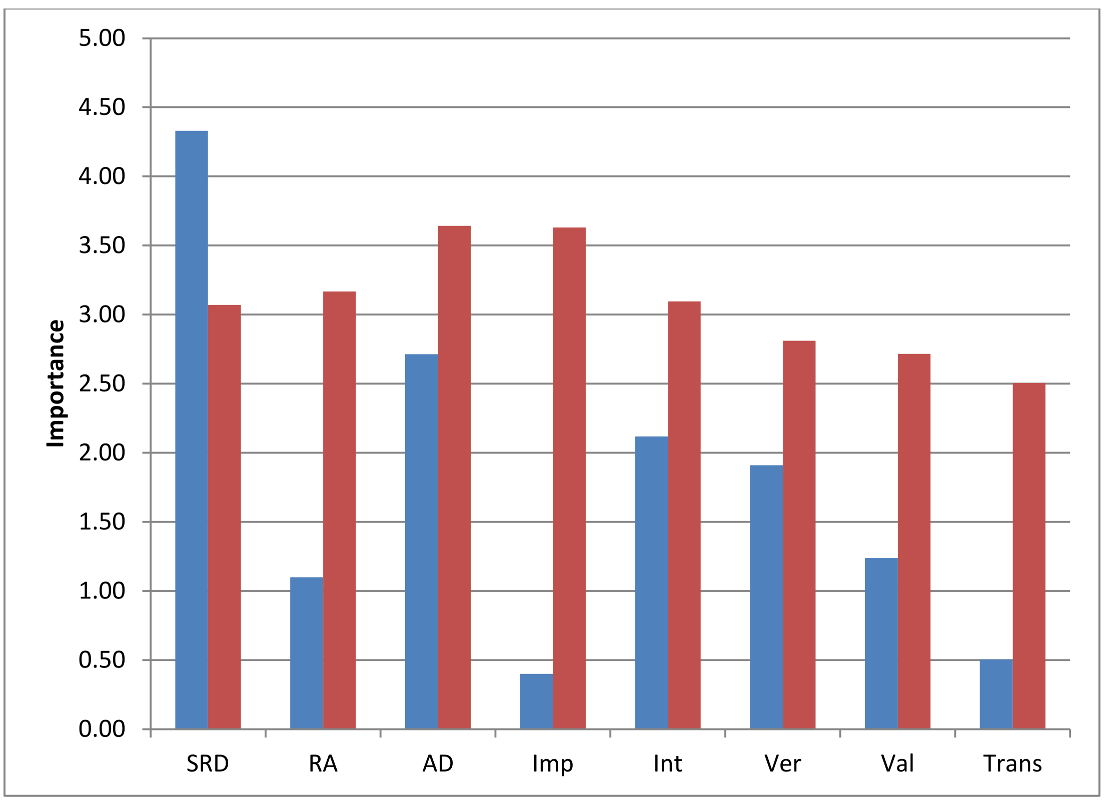

Figure 12: Combined Technical Process Scores

Since RA is derived from the initial requirements, it may be that the literature leaves it to the reader to perform the engineering activities to go from requirements to design and does not devote as much time to explaining that effort. However, for AFRL S&E‟s it is an important piece of the design process to ensure stakeholders‟ concerns are matched to performance specifications. Implementation consists of designing and testing the subsystems and components. This being an internal process that feeds into the final, assembled product, the literature may place little emphasis compared to other processes. AFRL S&E‟s noted that constructing a prototype to show a user early and quickly was a key step that allowed feedback to modify design or requirements.

The literature also shows little emphasis on transition compared to AFRL S&E‟s. This could be an assumption in the literature that if you research, design, build and test successfully consumers will buy your product. In the Lab, product transition is less of a guarantee and subject to separate acquisition organizations that require advocacy and funding above that required for the rapid development project. The remainder process scores are comparable to each other.

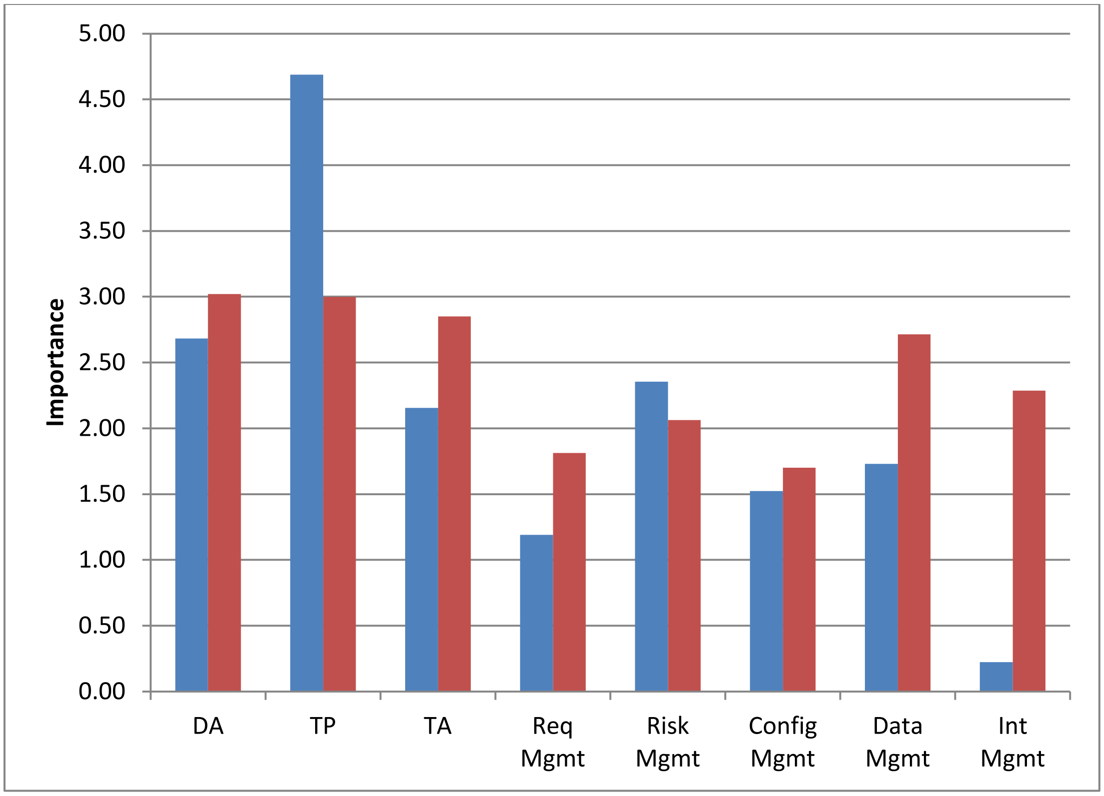

Figure 13: Combined Technical Management Process Scores

Next, we will examine the technical management process scores. The main discrepancies are in Technical Planning and Interface Management. The literature places the most emphasis in determining the scope of the technical effort and developing a systems engineering plan to cover all aspects of a project. However, many of the interviewees attested that iterating on a design with feedback from the user was more important than developing a "fire-proof" plan. Interface Management was emphasized more among AFRL S&E"s than in the literature. This could be due to the integrated nature of defense products especially with sensor technologies that are designed to push information and intelligence products across an enterprise of users. The literature is either not concerned primarily with products integrated with external interfaces such as designing a portable CD player or assumes that the external interfaces exist and are well defined like the USB ports on your personal computer and thus assigns it relatively little importance.

To summarize the technical process scores, the literature and AFRL S&Es agreed to the general principle of "up-front and early" when conducting rapid development. The literature emphasized Stakeholders Requirements Development and Architecture Design. The S&Es were more uniform in their results and agreed on the importance of Architecture Design but also emphasized Implementation. The technical management processes were also generally similar, but the literature showed Technical Planning was of stronger importance and Interface Management of lesser importance when compared to the AFRL S&E scores.

A possible explanation for differences in both analyses is the "practitioner vs. pundit" effect. With respect to the "pundits", the content analysis of the literature has shown a strong preference for one process over another, in this case Tech Planning vs Interface Management. The authors may be assuming a level of understanding within their intended audience that masks the relative importance of each process. They could also overemphasize processes that either were ignored in the past or were executed poorly. From the point of view of the "practitioner" there may be a stronger emphasis on the processes that are requirements due to policy or practicality. Most of the technical process scores cluster around 2.75, with a score of 3 meaning the process was "important" vice "very important" or "not important" and the activities within the process were neither fully implemented nor fully ignored. In this study, the literature deems Implementation as "not important". This contrasts with the AFRL engineers which score it as "important". In reality, a project must implement the design, otherwise there would be no product to test or deliver.

Conclusions

This study set out to determine if there were key Systems Engineering Processes emphasized by product development literature that could be implemented within AFRL rapid development projects. From the literature, Stakeholders Requirements Definition, Architecture Design and Technical Planning were strongly emphasized when compared to the other processes. This agrees with the anecdotal lesson learned “plan up front and early”. While interviewees agreed that up-front technical planning was important to maintaining short schedules, progress in delivering a prototype iterating the design based on user feedback was as important. Based on these results, project managers and chief engineers participating in future AFRL CP3 and other rapid development projects should focus on these processes early on in the projects‟ lifecycle. Senior leaders should encourage training in developing project requirements, architectures and holding meaningful reviews.

Recommendations and Areas of Future Research

The framework developed in this study could serve as a guide for program managers of rapid development projects. AFRL‟s Core Process 3 teams could be made aware of the findings codified by modifying the current AFRL instruction for CP3 or as an accompanying AFRL Manual.

The outcome of the importance of the SE processes was highly dependent on the materials chosen. The methodology can be implemented further by including more product development literature or by focusing on a particular field (i.e. software development) and comparing to case studies within that field.

This research was conducted to follow up previous studies of rapid development within AFRL and the AFIT theses of Capt David Solomon and Majors Behm, Pitzer and White should also be consulted for additional topics.

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APPENDIX A: SE PRODUCTS SURVEY

SME #___

Interview Questions

Background

Average funding of project?: ________ Average schedule? _______ Number of projects? _____

Tell me about how you approach SE in rapid reaction

(Walk through 16 disciplines)

Technical Management Processes	Technical Processes
Decision Analysis	Stakeholders Requirements Definition
Technical Planning	Requirements Analysis
Technical Assessment	Architectural Design
Requirements Management	Implementation
Risk Management	Integration
Configuration Management	Verification
Technical Data Management	Validation
Interface Management	Transition

SME #___

Technical Processes	Category		
	Fully	Partially	Did Not
Stakeholders Requirements Definition			
How do you flush out system constraints?	☐	☐	☐
Do you craft successful validation criteria?	☐	☐	☐
Do you develop a concept document or OV-1?	☐	☐	☐
Requirements Analysis			
Are system functional requirements created?	☐	☐	☐
Are system performance requirements derived?	☐	☐	☐
Do you consider architectural constraints?	☐	☐	☐
Do you have a verification strategy for the end product?	☐	☐	☐
Architecture Design			
Is an architecture baseline established (DoDAF)?	☐	☐	☐
Are system element descriptions crafted?	☐	☐	☐
Do you have interface requirements?	☐	☐	☐
Do you create a system integration plan?	☐	☐	☐
Implementation			
Do you have implementation constraints?	☐	☐	☐
Is there an implementation strategy to deal with the constraints?	☐	☐	☐
Is each planned subsystem built?	☐	☐	☐
Do you provide initial operator training/evaluation?	☐	☐	☐
Integration			
Do you use simulations?	☐	☐	☐
Do you write component test reports?	☐	☐	☐
Are there problem resolution reports?	☐	☐	☐
Do you have interface control documents during integration?	☐	☐	☐
Verification			
Do you write a test plan/ test cards?	☐	☐	☐
Do you write test reports for the whole system and compare to the requirements?	☐	☐	☐
Do you document corrective actions?	☐	☐	☐
Validation			
Do you participate in a demo or exercise?	☐	☐	☐
Is there an independent evaluation?	☐	☐	☐
Is there an Operational Assessment in the field?	☐	☐	☐
Transition			
Do you provide a fielded system?	☐	☐	☐
Do you test for interoperability certifications?	☐	☐	☐
Is there a formal safety evaluation?	☐	☐	☐
Do you write a transition plan?	☐	☐	☐
Are the –ilities considered?	☐	☐	☐

SME #___

Technical Management Processes

Decision Analysis	Fully	Partially	Did Not
Do you define and evaluate alternatives?	☐	☐	☐
Is there relevant stakeholder buy-in?	☐	☐	☐
Define strategy and success criteria	☐	☐	☐
Decision rational documents?	☐	☐	☐
Lessons Learned?	☐	☐	☐
Technical Planning			
Work Breakdown Structure	☐	☐	☐
Roles and Responsibilities/ Team Charter	☐	☐	☐
Systems Engineering Plan	☐	☐	☐
Chief Engineer and Key Resources	☐	☐	☐
Integrated Master Plan	☐	☐	☐
Technical Assessments			
System Functional Review	☐	☐	☐
Preliminary Design Review	☐	☐	☐
Critical Design Review	☐	☐	☐
Test Readiness Review	☐	☐	☐
System Verification Review	☐	☐	☐
Interim Program Reviews	☐	☐	☐
Requirements Management			
Project performance measures	☐	☐	☐
Traceability matrix/ Impact assessments	☐	☐	☐
Change request documentation	☐	☐	☐
Risk Management			
Risk matrix	☐	☐	☐
Risk tracking	☐	☐	☐
Risk priority	☐	☐	☐
Risk mitigation plan	☐	☐	☐
Configuration Management			
Configuration baseline	☐	☐	☐
Configuration Control Document/Board/ Charter	☐	☐	☐
Documented impact of change request	☐	☐	☐
Functional Configuration Audit	☐	☐	☐
Physical Configuration Audit	☐	☐	☐
Data Management			
Common, managed data storage	☐	☐	☐
Data rights, manuals, documentation	☐	☐	☐
Security classification guide	☐	☐	☐
Interface Management			
ICWG documented interface specs	☐	☐	☐
Interface compliance matrix	☐	☐	☐

APPENDIX B: LITERATURE SCORES

Raw Scores (frequency count)

	Stakeholders Requirements Definition	Requirements Analysis	Arch Design	Implementation	Integration	Verification	Validation	Transition	Totals
Wheelright and Clark	12	4	8	4	7	6	6	0	47
Cooper/ Stage Gates	9	1	3	1	2	4	3	2	25
Smith and Reinertsen	4	2	9	0	3	1	0	1	20
PLM	3	1	3	0	4	2	1	0	14
RAD- Total	6	2	2	0	2	4	2	1	19
RAD- Standard, 1995	3	1	1	0	1	3	1	1	11
RAD- Implemented, 2000	3	1	1	0	1	1	1	0	8
PDMA	12	2	5	1	2	2	2	3	29
Handbook 2, 2005	11	1	4	0	1	1	1	2	21
Toolbook 3, 2007	1	1	1	1	1	1	1	1	8

	Decision Analysis	Technical Planning	Technical Assessment	Requirements Management	Risk Mgmt	Config Mgmt	Tech Data Mgmt	Interface Mgmt	
Wheelright and Clark	5	10	3	1	2	0	0	0	21
Cooper/ Stage Gates	5	6	4	0	4	0	0	0	19
Smith and Reinertsen	3	7	2	2	7	2	2	1	26
PLM	1	3	0	1	0	3	4	0	12
RAD- Total	1	3	1	2	1	2	2	0	12
RAD- Standard, 1995	1	2	0	0	1	2	0	0	6
RAD- Implemented, 2000	0	1	1	2	0	0	2	0	6
PDMA	7	7	8	1	5	1	1	1	31
Handbook 2, 2005	6	6	7	0	4	0	0	0	23
Toolbook 3, 2007	1	1	1	1	1	1	1	1	8

Normalized Scores

Technical Processes	SRD	RA	AD	Imp	Int	Ver	Val	Trans
Wheelright and Clark	5.00	1.67	3.33	1.67	2.92	2.50	2.50	0.00
Cooper/ Stage Gates	5.00	0.56	1.67	0.56	1.11	2.22	1.67	1.11
Smith and Reinertsen	2.22	1.11	5.00	0.00	1.67	0.56	0.00	0.56
PLM	3.75	1.25	3.75	0.00	5.00	2.50	1.25	0.00
RAD	5.00	1.67	1.67	0.00	1.67	3.33	1.67	0.83
PDMA	5.00	0.34	0.86	0.17	0.34	0.34	0.34	0.52
Average	4.33	1.10	2.71	0.40	2.12	1.91	1.24	0.50
St Dev	1.15	0.55	1.57	0.66	1.64	1.19	0.93	0.44
Percent of Total	30.3%	7.7%	19.0%	2.8%	14.8%	13.3%	8.7%	3.5%
Percent St Dev	22.93%	11.07%	31.38%	13.15%	32.87%	23.84%	18.53%	8.89%

Technical Management Processes	DA	TP	TA	Req Mgmt	Risk Mgmt	Config Mgmt	Data Mgmt	Int Mgmt
Wheelright and Clark	2.50	5.00	1.50	0.50	1.00	0.00	0.00	0.00
Cooper/ Stage Gates	4.17	5.00	3.33	0.00	3.33	0.00	0.00	0.00
Smith and Reinertsen	2.14	5.00	1.43	1.43	5.00	1.43	1.43	0.71
PLM	1.25	3.75	0.00	1.25	0.00	3.75	5.00	0.00
RAD	1.67	5.00	1.67	3.33	1.67	3.33	3.33	0.00
PDMA	4.38	4.38	5.00	0.63	3.13	0.63	0.63	0.63
AVERAGE	2.68	4.69	2.15	1.19	2.35	1.52	1.73	0.22
St Dev	1.30	0.52	1.75	1.17	1.81	1.65	2.03	0.35
Percent of Total	16.2%	28.3%	13.0%	7.2%	14.2%	9.2%	10.5%	1.3%
Percent St Dev	26.04%	10.46%	35.01%	23.44%	36.22%	33.10%	40.56%	6.94%

APPENDIX C: SME SCORES

Background Data

ID	Yrs RD Exp	Min Sched (years)	Max Sched (years)	Min Budget ($'000)	Max Budget ($'000)	Min Team Size	Max Team Size
1	6	0.5	3	500	3000	1	10
2	5	0.5	2	500	1000	3	12
3	2	2	2	70000	70000	90	90
4	2	0.5	1.5	500	2000	6	12
5	3	1	1.5	600	1000	3	6
6	2	1	2	20000	100000	20	50
7	3	0.5	2	500	2000	5	12

Technical Process Scores

ID	SRD	RA	AD	Imp	Int	Ver	Val	Trans
1	3.40	3.50	2.50	3.00	3.50	1.00	1.00	2.33
2	4.00	4.00	4.33	4.75	2.00	2.00	1.67	1.00
3	3.00	3.00	2.00	3.00	2.50	3.00	5.00	3.00
4	1.50	2.33	3.67	3.00	3.50	3.00	3.00	3.00
5	3.00	3.00	5.00	3.00	2.00	2.00	2.33	3.00
6	5.00	5.00	4.00	5.00	4.50	5.00	4.00	4.20
7	1.67	1.50	4.00	3.67	3.67	3.67	2.00	1.00

Technical Management Scores

ID	DA	TP	TA	Req Mgmt	Risk Mgmt	Config Mgmt	Data Mgmt	Int Mgmt
1	3.25	2.00	1.00	1.50	1.00	1.00	2.00	1.00
2	3.00	4.40	2.33	1.67	2.00	1.00	4.00	3.00
3	2.60	2.60	2.20	2.33	2.50	2.20	4.00	2.00
4	4.00	3.40	3.00	1.67	1.00	1.50	1.00	1.00
5	3.50	2.50	2.67	3.00	3.00	1.00	1.00	1.00
6	3.00	4.33	5.00	2.33	5.00	3.00	4.00	3.00
7	1.80	1.00	2.60	1.00	1.00	2.20	3.00	5.00

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14. ABSTRACT
In the current environment of military operations requesting faster delivery schedules to counter insurgent tactics, the engineering team often searches for how to quickly deliver the "80% solution", typically in 6-12 months. These are labeled rapid development projects. A content analysis of best practices in commercial product development literature, where time to market is often a driving factor, was accomplished showing varying emphasis of systems engineering technical and technical management processes. Technical Planning, Stakeholders Requirements Development, and Architecture Design were identified as important processes. This analysis confirms preconceived notions of "plan upfront and early" by emphasizing the SE processes of Stakeholder Requirements Definition, Architecture Design and Technical Planning. A purposive sampling of AFRL rapid development program managers and engineers was conducted to identify important SE processes and compared to the literature content analysis. The results of this sampling did not strongly emphasize one process over another however Architecture Design, Implementation scored higher among Technical Processes. Decision Analysis, Technical Planning, Technical Assessment and Data Management scored slightly higher among Technical Management Processes. Anecdotal evidence also emphasized iterating prototype designs based on early customer feedback, focusing mostly on critical risks and holding more reviews early in a project schedule until a trust in the team is built.

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